On the Absence of Cosmic Acceleration

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ABSTRACT

The unexpected faintness of distant Type Ia Supernovae (SNe) has been used by many to argue for an accelerated expansion of the universe. However, observations of nearby SNe show high velocity and polarized features in SNe Ia, indicating that the single degenerate paradigm for many Type Ia SNe is drastically and catastrophically invalid. By now it appears that an extreme version of the axisymmetry seen in SN 1987A is the correct paradigm for many SNe Ia and Ic, and that these are both core-collapse *and* thermonuclear objects, which leave weakly magnetized, rapidly spinning (∼2 ms) pulsar remnants. In this paradigm, a Ia/c is produced from the merger of two degenerate cores of common envelope Wolf-Rayet stars, or of two CO white dwarfs. Thus the same explosive mechanism that underlay 10–15 $M_\odot$ in SN 1987A, underlies only 0–1.5 $M_\odot$ in SNe Ia/c. Its now visible polar blowout features produce the observed high velocity and polarized spectral features in Ia's, and its equatorial bulge is much brighter in Ia's, due to the greater fraction of ^{56}Ni contained within it. Such merger SNe become classified as Ia's when viewed from the merger equator, and sometimes Ic's when viewed from the poles, where a hypernova signature and a gamma-ray burst will be observed for lines of sight close to the merger axis. Thus cosmology determined strictly from Ia's alone is flawed at its very foundation: the local sample is selectively biased. The problem may be due to SNe from a class spanning a wide range of lower intrinsic luminosities, previously unaccounted for in the local sample, which were unknowingly included in the distant sample, and the result was distant SNe Ia which appeared to be too faint for their redshifts. When the errors introduced by this and other processes are taken into account, there may be no cosmic acceleration effect in distant SNe.

Subject headings: cosmology:observations—pulsars:general—white dwarfs—stars: Wolf-Rayet—supernovae:general—supernovae:individual (SN 1987A)

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1. Introduction

Type Ia supernovae (SNe Ia) have been used by at least two groups, and all without any explicit foreknowledge of their progenitors,[1] to argue that the expansion of the universe is accelerating, and hence for the existence of "dark energy," or a cosmological constant, Λ (see, e.g., Riess et al. 1998; Perlmutter et al. 1999). This has the appearance of convenience, as it helps several other lines of inquiry, including the scale size of the fluctuations of the surface of last scattering of the cosmic microwave background (CMB), and measurements of the clustering mass on large scales (see, e.g. Eisenstein et al. 2005), converge to a consistent set of parameters, generally $\Omega_m \sim 0.3$ and $\Omega_\Lambda \sim 0.7$. However, at present SNe Ia represent the only firm, direct evidence for the existence of dark energy (see, e.g., Conley et al. 2006).

If dark energy has been convenient for cosmologists, it is certainly not so for the Standard Model, which allows no such subtle effect by 120 orders of magnitude (Weinberg 1989). Still, a lot of other recent efforts have gone into shoring up the case for cosmic acceleration (see, e.g., Clocchiatti et al. 2006), and there is no doubt that all are seeing the same effect. In addition, many have pointed out that the effect is still present even without using the width-luminosity (WL) relation, determined for local SNe Ia a decade earlier by Phillips and others (see, e.g., Phillips et al. 1999, and references therein),[2], to correct the Ia luminosities. However, recent observations of nearby SNe have shown that Ia's have high velocity and polarized line features at the few % level (Leonard et al. 2005; Mazzali et al. 2005a), as well as a few tenths of a % mean continuum polarization. Of great concern, is a potentially continuous faint class of SNe which, even though some members can be excluded from samples on the basis of high Δm_{15} to be used for the WL correction, could have less extreme members included in distant samples (Benetti et al. 2005, hereafter B05). In addition, statistical considerations alone may rule out *any* cosmology derived from SNe Ia (Vishwakarma 2005). And finally, core-collapse in Ia's may be *necessary* to explain the abundance of Zn (Kobayashi et al. 2006).

In this letter I argue that there is no direct evidence for cosmic acceleration or dark energy because the local sample of SNe is selectively biased due to these effects, and in part because of widespread ignorance and prejudice about the true nature of SNe Ia.

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[1]In a Las Campanas 2.5-m run on SN 1987A during 1995 Feb. my late colleague, Dr. Jerry Kristian, mentioned to me that he considered the Ia cosmology effort "a perversion of the science," because no one knew what SNe Ia really were.

[2]Phillips and Suntzeff were so occupied by this effort, that the proceedings for the "SN 1987A – Ten Years After" conference have yet to see the light of publication (Middleditch et al. 2000a), and likely never will.

2. What are SNe Ia/Ic?

In spite of initial wild overestimates for the masses of some SNe Ic progenitors (SN 2002ap, 2003dh – Mazzali et al. 2002, 2003), no Ia or Ic progenitor has ever been identified (see, e.g., Maund, Smartt, & Schweizer 2005), thus they cannot be massive stars. The "usual" Ia paradigm, (gradual) accretion-induced collapse of a white dwarf, or single degenerate (SD), suffers from the absence of H and He which should have been advected from the mass-donating companion star. There is also the difficulty in generating more than 0.1 $M_\odot$ of ^{56}Ni from a single ignition source (Brown et al. 2005), though multiple sources have been discussed by Röpke et al. (2006). Finally, in addition to their high velocity and polarized features, Ia's also show a broad range of diversity in their velocity gradients and correlations with Si line ratios and $\Delta m_{15}(B)$ (Hachinger, Mazzali, & Benetti 2006; James et al. 2006), all unlikely side effects of simple thermonuclear disruption.

The morphology of the explosion of SN 1987A has now been clear for a number of years (NASA et al. 2003; Wang et al. 2002; Middleditch 2004, hereafter M04). A polar blowout feature (PBF) approaches at about 50° off our line of sight (see, e.g., Sugerman et al. 2005). It partially obscures an equatorial bulge/ball (EB), behind which a part of the opposite, receding PBF is visible. The PBFs and bulge are approximately equally bright.

SN 1987A is thought to have ejected about 10–15 $M_\odot$ (see, e.g., Woosley 1988),[3] and, because of the blue supergiant nature of the progenitor (Sanduleak 1969), the rings (Burrows et al. 1995), the "mystery spot" (Meikle, Matcher, & Morgan 1987; Nisenson et al. 1987), the mixing (Matz et al. 1987; Cook et al. 1988), the polarization (Barrett 1987), and the possible 2 ms pulsar remnant (Middleditch et al. 2000b),[4] is very likely to have been the result of a DD merger of two stellar cores. Occam's Razor alone would argue that Ia's and Ic's are the result of the same process(es), but there are many other good reasons. If Ia's and Ic's are the result of common-envelope Wolf-Rayet (WR) DD mergers (see, e.g., DeMarco et al. 2003; and the data in Górny & Tylenda 2000; Howell et al. 2001), or CO-CO white dwarf mergers which are common in globular clusters (see, e.g., Chen, Middleditch, & Ruderman 1993),[5] then the limit for mass ejected is near 1.5 $M_\odot$, consistent with the $\sim$1

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[3] All such models are, of course, invalid for double-degenerate (DD) merger SNe due to the differences in mixing and the core-collapse process.

[4] On two occasions shortly before his death, I discussed the pulsar search effort on SN 1987A with Kristian, and the only thing both of us could conclude was that the 2.14 ms signal was very likely real. This is still the case.

[5] This accounts for gamma-ray bursts (GRBs) in both Population I and II (see, e.g., Mannucci, Della Valle, & Panagia 2006). In addition, the difference in the pulsar population of 47 Tuc and Ter 5, with

$M_\odot$ limit of ^{56}Ni produced in SNe Ia.

Further, if SNe Ia/c are the result of the same explosive process that underlay 10–15 $M_\odot$ in SN 1987A (core-collapse), but which instead only underlies 0.5 $M_\odot$, the outcome will be even more extreme than the geometry of the SN 1987A remnant. The PBFs will have higher velocities, and the equatorial/thermonuclear ball (TNB) will be much brighter due to the greater concentration of ^{56}Ni, but its expansion velocity will not necessarily be higher than in IIs, as the mean Z for the outer ejecta will be higher. Thus, there is no need to invoke exotic mechanisms such as "gravitationally confined detonation" to explain SNe Ia (Plewa, Calder, & Lamb 2004). When viewed close to the poles of the merger, one of the two PBFs will obscure the TNB (if there is sufficient mass above the merger pole(s)), and show lines of r-process intermediate mass elements (IMEs) from its end, and the SN will be classified as a Ic, and for views very close to the poles, a hypernova signature will be seen, in addition to a GRB (M04). Thus it should not be surprising that the faint GRB 031203 was associated with the bright SN Ic 2003bw (Malesani et al. 2004), but the other way around *would* be, as long as there were no late rebrightening, as was the case for GRB 050525A and SN 2005nc (Della Valle et al. 2006).

Unless the view *is* very near polar, this geometry will have no difficulty in producing split emission line(s) on rare occasions, as was seen in SN 2003jd, and thus again there is no need to invoke other explosion mechanisms (Mazzali et al. 2005b).[6] When viewed sufficiently far from the poles, the TNB will dominate the luminosity, Fe and Si absorption lines will appear, the SN will be classified as a Ia, but similar high velocity lines will also appear from the sides of the PBFs due to material advected from the TNB, in addition to IME lines, including Si again. The assumption implicit in Ia cosmology is that the TNB will be a standard candle which can be compared to the redshift of the host galaxy to determine the expansion properties of the universe. However, problems arise in the actual measurements of distant SNe Ia if classes of SNe exist, not accounted for in the local sample and/or the WL relation, which may differ from that of other SNe classes.

If Ia/c's are the result of DD merger-induced core-collapse, then what type of SNe, if any, are the result of thermonuclear disruption? On average these will be brighter than Type IIs by about 10–50%, assuming 0.1 $M_\odot$ of ^{56}Ni from Brown et al. (2005), and don't

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its lower luminosity/duty-cycle (the latter so much so as to overcome the effects of the former) pulsars (Ransom et al. 2006), confirms the DD merger origin for those in the non-core-collapsed 47 Tuc (Chen & Ruderman 1993; M04).

[6] And there is absolutely no need to invent an entire population (III) to account for GRBs (Conselice et al. 2005; M04).

eject much high velocity matter, but H and He from the mass-donating companion will be advected by the SN wind and lead to a classification as some kind of Type II SN. The prime candidates are Type II-L SNe, which may not have sufficient, unclumped mass in their TNBs to be bolometric, hence the linear decline of luminosity with time (Filippenko 1997). On average these differ from IIPs by about the same 10–50% in Richardson et al. (2002), excluding the overluminous II-Ls 1961F, 1979C, 1980K, and 1985L, and allowing for work done lifting ejecta.

3. The Evidence

3.1. The Ubiquitous High Velocity Features in Ia's

In the DD paradigm these (Mazzali et al. 2005a) result from SNe Ia having two PBFs of finite angular width. The half width angle of the PBFs can be estimated from the ratio of the numbers of nearby SNe from catalogs. If we let R_1 be the TNB radius, below which sufficient visible EW in Si and Fe lines would result in the SN Ia/c being classified as a Ia, R_2 the radius of the limit cones of the PBFs at the same given time, θ the half angle of the PBF cones, ζ the half angle of the cone circumscribed around the (assumed spherical) TNB and containing the circular boundary of the base of one PBF limit cone (the visibility divider between Ia's and Ic's), and $\phi = sin^{-1}(R_1 {R_2}^{-1})$, then $\theta = \zeta + \phi$.

Counting SNe with radial velocities $< 10,000$ km s^{-1}, from SN 1995O to 2004cg in the SAI catalog (Tsvetkov et al. 2005), gives 282 Ia's, 66 Ic's, and 301 Type II SNe,[7] for a Ia:Ic ratio of 4.27:1. Using a 1:5 ratio for R_1 vs R_2 (which might be an overestimate) we get $1 - cos\zeta = 5.27^{-1}$, or $\zeta = 35.9°, \phi = 11.5°$, and $\theta = 47.4°$, a value big enough so that high velocity contributions to lines from the PBFs will almost always occur, no matter what the orientation from which SNe (classified as Ia) are viewed.

The 4.27:1 ratio of the numbers of local SNe Ia:Ic also points out a problem with the distant SNe, where a similar count yields 353 Ia's, 75.5 IIs and 7.5 Ia's for a Ia:Ic ratio of 47:1. This discrepancy has been pointed out by others (Jensen 2004), and may be too extreme to be explained by selection effects. The observing mode in the high z searches has sometimes only distinguished between Ia's and "other," which does not inspire much confidence that selection effects don't differ between the local and distant samples. When a completely classified long list includes only Ia's, a few IIs, and no Ic's, the situation could be even worse.

[7]Excluding Type IIn's.

It is possible that, because of the assumption of the wrong paradigm (SD) for SNe Ia, and the desire to avoid contaminating the sample of Ia's by including SNe which appeared too "Ic-ish," with too much EW in IME lines and such, a local sample of Ia's was selected in which many were viewed very close to the equator of the DD merger. This would mean that many other Ia's would not conform to the WL relation, but may have been included in the distant samples.

B05 have divided SNe Ia into three categories, FAINT, and the brighter high and low velocity gradient (HVG and LVG) SNe. In the PBF/TNB paradigm, FAINT Ia's are indeed intrinsically faint, producing little ^{56}Ni, and their high velocity gradients and $\sim$9,000 km s^{-1} expansion velocities are the result of only a small amount of material in their ejecta, and thin polar ejecta and/or a near-equatorial view. The HVG SNe Ia are brighter, due to more ^{56}Ni, and have $\sim$12,000 km s^{-1} expansion velocities, but are viewed substantially off the DD merger equator, where the opacities of conal PBF and advected TNB material diminish rapidly with time. The LVG SNe Ia are also bright, but have a low velocity gradient and $\sim$10,000 km s^{-1} expansion velocities because they are observed from near the equator of the DD merger. The increasing/decreasing evolution of $R\,(\text{Si II})$ (i.e., temperature) with time of HVG/LVG SNe Ia is consistent with this interpretation (Figure 2 of B05).

Four out of five of the FAINT Ia's in B05 fall below the WL relation by 1–2 *whole* magnitudes, and yet their $\Delta m_{15}(B)$'s fall just barely outside the validity range for the WL relation (<1.75). Thus measurement errors alone will lead to contamination, but if these represent a continuous class, then others will exist well within the range of validity but which are also below the WL relation by up to one whole magnitude. Similar systematic differences may also exist within the brighter HVG and LVG samples, and the effect need only average near 0.25 magnitudes to account for all of Λ. In principle, if we could ensure that distant Ia's are all extreme LVGs, then Ia cosmology might produce a valid answer. In reality, however, problems arise because the FAINT, HVG, and LVG classification of SNe Ia maps a continuous class of at least two independent variables (intrinsic luminosity and observational inclination) into three arbitrary categories, the local sample of SNe Ia is selectively biased, and the signal-to-noise ratios from the most distant SNe are low.

3.2. Polarization

Continuum polarization near the 0.9–0.4% level was detected in the Type IIP SN 1987A (Barrett 1987), two out of three Type IIs observed by Wang et al. (1996), 1994Y, and

1995H, in SN 1993J at nearly *twice* that level (Trammell, Hines, & Wheeler 1993),[8] and 0.2–0.5% in the Type IIP SN 1999em, 7 to 159 days after maximum, by Leonard et al. (2001). Thus, continuum polarization in IIs is (and should be) common due to their PBFs having approximately equal brightness as their EBs.

Continuum polarization is markedly low or absent in Ia's, typically <0.2%, with the exceptions of SN 1996X at 0.3% (Wang, Wheeler, & Höflich 1997), the FAINT SN 1999by at 0.3–0.8% (Howell et al. 2001), the LVG SN 2001el, near 0.2–0.3% (Kasen et al. 2003), the LVG SN 2003du at 0.3% (Leonard et al. 2005), and SN 2005hk at 0.4% (Chornock et al. 2005). This is exactly what is expected for Ia's because the TNB is roughly spherical, and dominates the luminosity of Ia's, where the PBFs are viewed from the sides, but are not bright enough to matter. SN 1999by was highly polarized because it was a faint SN Ia, and the PBFs did matter. SN 2005hk was less luminous (likely a member of the FAINT class) than 2001el, and thus its level of continuum polarization is higher.

In contrast, the Ca II 800 nm IR triplet and the Si II λ 6355 $\AA$ (absorption) lines in nearly all SNe Ia are very highly polarized, particularly those with high velocities, which is a result of the lines preferentially originating from the sides of the PBFs, visible (by definition) in all Ia's (Kasen et al. [2003] on SN 2001el "The high velocity triplet absorption [800nm Ca II] is highly polarized . . . "; Wang et al. [2003] ". . . is distinct in velocity space from the photospheric Ca II IR triplet and has a significantly higher degree of polarization (≈0.7%) and different polarization angle than the continuum . . . kinematically distinct feature with matter distributed in a filament . . . almost edge-on to the line of sight . . . ").

Line polarization occurs in increasing strength in overluminous, normal, subluminous, and high velocity SNe (HV – broad lines, blueshifted up to 15,000 km s^{-1}) in observations (Leonard et al. 2005), as well as naturally in the TNB/PBF paradigm. Clearly the polarization of Ia's should increase as apparent luminosity (the visible TNB) decreases. The further increase of polarization with velocity should vary inversely with PBF mass, until so little matter remains to be ejected into the PBF that it becomes optically thin.[9] Thus the strength of the line polarization is only 0.2% in the overluminous SN 2003du, but is 2% in lower luminosity HV SNe such as 2004dt (Wang et al. 2004), again consistent with the PBF/TNB

[8]In the case of SN 1993J, the PBFs are, and/or appear longer due to the low amount of H, and/or a near equatorial view, or both. Thus 1993J is a "missing link" between Type II and Type Iabc SNe.

[9]This circumstance could explain the relative dearth of CO-CO WD merger SNe Ic in ellipticals (van den Berg, Li, & Filippenko 2005 – ignore the erroneous conclusion in the abstract), as matter in excess of 1.4 $M_\odot$ from two WDs is rare. This picture of "leaner" mergers in non-actively star-forming galaxies is consistent with Sullivan et al. (2005), and may also mean that the PBFs run out of matter before the TNBs as total merged mass decreases, leading to more Ia's.

paradigm for Ia/c's.

Polarization in Ic's is more complicated, as those seen most end-on will also have blueshifted HV lines, but will appear to be spherical, so little polarization will result. However, when both PBFs are visible, the extension in one direction will produce polarization, just as it does in Type IIs, and may exceed that in IIs due to the rapid extension of the higher velocity PBFs and the obscured, or even the non-obscured, but faded, EB/TNB. These are the Ic analog of the HV Ia's. The continuum polarization of the Ic SN 2002ap rose from 0 to 0.5% from -6 to +3 days from maximum (Wang et al. 2003), and later to 1.0% and 1.6% on days 16 and 37 respectively (Leonard et al. 2002).

3.3. The Merger Paradigm and the Luminosities of SNe

The merger paradigm also explains why Types Ib and II SNe produce relatively little ^{56}Ni, because their C and O layers are diluted with He, in addition to H for IIs, due to the merger process. Aside from Type II-L SNe, Type IIs, initiated through Fe photodissociation catastrophe, suspected for SN 1986J (Bietenholz, Bartel, & Rupen 2004), may so far be the only known exceptions to the merger paradigm, and the vast bulk of these, i.e., those which do not continue to collapse into black holes, should be brighter than DD Type IIs due to their C and O layers remaining relatively undiluted at the time of core-collapse, in addition to their embedded, strongly magnetized pulsars. In DD merger-induced SNe Ia/c, which all lack H and He, not only are the C and O layers undiluted, they are intimately mixed.

3.4. Conclusion

I have argued above that SNe Ia and Ic are the result of the same process, the DD merger-induced core-collapse of common envelope WR stars or CO-CO white dwarfs. I have further argued that many distant Ia's in a continuous class will have Δm_{15}'s within the acceptable limit, but low luminosities wrt the local sample, whether the WL relation is used or not. In addition, the high velocity of the small amount of matter in near-polar ejecta of Ia's exposes a fraction of the Ia TNB to non-equatorial views during the interval when Δm_{15} is measured. These SNe were also frequently not included in the local sample for a number of reasons, including appearing to be too "Ic-ish." Thus, yet another systematic bias entered the local sample of SNe in favor of those which dimmed too quickly due to an equatorial view of the DD merger. However the bias for the most distant, and hence low signal-to-noise SNe, is probably not the same, leading to less discriminating inclusion in the sample, skewing the results. A 7% Ibc contamination level is sufficient to produce $\Omega_\Lambda = 0.7$ from no effect (Homeier 2005).

Using astronomical sources of any kind to determine the nature of the universe is a tough business. Divining the structure of SNe using only spectroscopic data (and even the occasional polarization spectrum), an inverse problem for which very little progress has been made over several past decades, only increases the difficulty immeasurably. In SN 1987A nature has revealed the origin and structure of most SNe, including SN 1993J, and all we have to do is to pay attention. The SN Ia cosmology effort sets all records for blood[10] and treasure spent on a problem in astronomy. It was a gamble, but one that ultimately didn't pan out. The attempt to use a misunderstood phenomenon to measure cosmological parameters was perhaps understandable, but ultimately unwise.

Supernovae are indeed wondrous objects, with up to 99% resulting from DD merger-induced core-collapse. These may all produce ∼2 ms pulsars which, in their first few seconds after birth, may very well be the only frequently detectable gravitational radiation sources, and which, for at least a few years, shine in the optical band (Middleditch et al. 2000b). Many of their progenitors are not massive stars, and many produce jets, GRBs, and what astronomers have dubbed "mystery spots," "hypernovae," "collapsars," " supranovae," and my personal favorite, "The Beam from Hell," from what could appear to be unremarkable 20th magnitude blue stragglers, which can incinerate half the planet from a great distance with little or no warning. What they are *not*, however, are easily utilized standard candles, and $\Omega_\Lambda = 0.7$ may *not* be the "correct" answer. It may be impossible to get a "clean" sample of SNe Ia (Benetti et al. 2004; Blondin et al. 2005).

The attempt to use SNe IIP to measure cosmological parameters (see, e.g., Höflich et al. 2001; Nugent et al. 2006), faces the difficulty that even though most of these result from DD mergers of more massive stars, then, like SN 1987A, they will still manage to produce beams/jets which may or may not impact their previous polar ejection to produce a "mystery spot," (or two).

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[10] We're all a decade older.

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